

CHAPTER 3

SUBGRADE EVALUATION AND PREPARATION

3-1. General. The primary factors affecting subgrade suitability are listed in table 3-1.

3-2. Establishment of grade line. The subgrade line should be established to obtain the optimum natural support for the pavement consistent with economic utilization of available materials.

a. Rock. Rock excavation is to be avoided for economic reasons. Where excavation of rock is unavoidable, undercut to provide for full depth of base course under surface courses.

b. Ground water. The subgrade line will be above the flood plain and a minimum of 2 feet above wet season ground water level. Where not practicable, provide for permanent lowering of water table by drainage. (See EM 1110-3-136).

c. Balancing cut and fill. Balancing cut and fill should be considered but may not be a controlling mobilization factor in the design and construction of airfield pavements. Optimizing subgrade support and drainage should take precedence over balancing cut and fill.

3-3. Subgrade evaluation test by CBR. The basic CBR test is performed on compacted samples of the subgrade soil after a 4-day soaking. Samples are prepared at varying moisture contents and with three differing compactive efforts. The complete procedure is illustrated in figure 3-1 and the test methods are described fully in MIL-STD-621, Method 101. CBR tests can also be performed on the subgrade soil in place or on undisturbed samples of the subgrade soil. However, for design the latter test is used only in special cases. See table 3-2 for additional guidance on the use of CBR tests.

3-4. Subgrade density and compaction. For the CBR method of design, the in-place densities of the subgrade soils for the design aircraft must be at least equal to the values specified in table 3-3. If natural densities are less than the required values, the subgrade may be treated by one of the following procedures, as applicable:

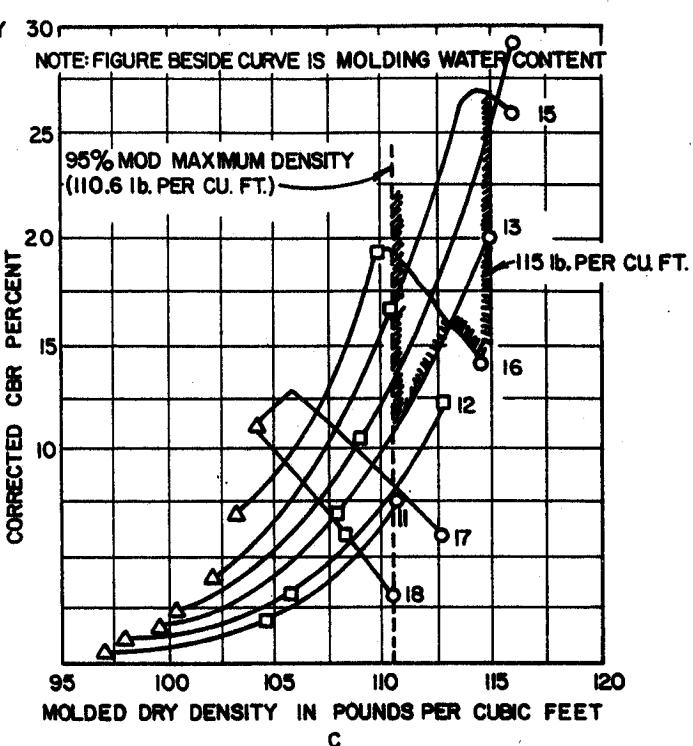
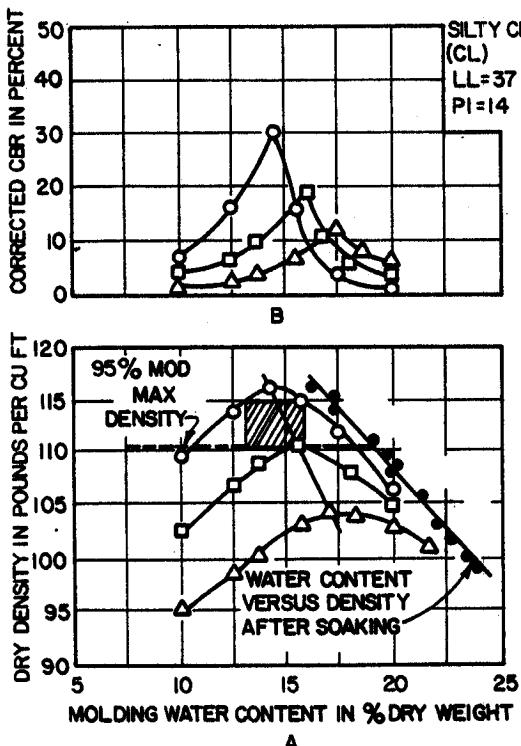
- Compact from the surface (cohesionless soils except silts).
- Remove, process to desired water content, replace in lifts, and compact. Minimum compaction for replaced soils is 95 percent for cohesionless and 90 percent for cohesive soils. For a definition of cohesive and cohesionless soils see MIL-STD-621, Method 101.

Table 3-1. Primary Factors Affecting Subgrade Evaluation and Suitability

<u>Factor</u>	<u>Remarks</u>
Characteristics of subgrade soils	Determine as shown in chapter 2.
Relative value as subgrade	See table 2-3.
Depth to rock	Determine during exploration of subgrade, if close to surface.
Depth to ground water	Determine seasonal fluctuations and effects of drainage.
In-place density of subgrade	From undisturbed samples or in-place tests.
Strength of subgrade:	
Natural condition	Determine during exploration and testing. Consider ultimate water contents after construction and their effect on strength characteristics. Follow procedure in MIL-STD-621 Method 101.
After compaction	
Ultimate values	
Settlement under fill loading	Determine effect of fill loading from consolidation tests. May require surcharge to consolidate a clay subgrade. Where local settlement data exists it should be used.
Frost susceptibility	See EM 1110-3-138 to determine during testing and exploration.
Weak or compressive layers in sub-soil	Consider compaction, removal and replacement with granular material, or design pavement on basis of in-place strength and density.
Drainage	See EM 1110-3-136.
Variability of generalized soil profile	May cause differential surface movements.

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Legend

○ = 55 blows/layer compactive effort

□ = 26 blows/layer compactive effort

△ = 12 blows/layer compactive effort

G = Specific gravity of soil

- Step A. Determine moisture/density relationship (MIL-STD-621 Method 100) at 12.26 and 55 blows/layer. Plot density to which soil can be compacted in the field - for clay of example use 95 percent of maximum density. Plot desired moisture content range - for clay of example use = 1-1/2 percent of optimum moisture content for approximately 13 and 16 percent. Shaded area represents compactive effort greater than 95 percent and within = 1-1/2 percent of optimum moisture content.
- Step B. Plot laboratory CBR (MIL-STD-621 Method 101) for 12.26 and 55 blows/layer.
- Step C. Plot CBR versus clay density at constant moisture content. Plot attainable limits of compaction from graph A, 110.6 and 115 pcf for example, hatched area represents attainable CBR limits for desired compaction (110.6 to 115 pcf) and moisture content (13 to 16 percent). CBR ranges from 11 (95 percent compaction and 13 percent moisture content) to 26 (15 percent moisture content and maximum compaction). For design purposes use a CBR at low end of range - in example use CBR of 12 with moisture content specified between 13 and 16 percent.

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FIGURE 3-1. PROCEDURE FOR DETERMINING CBR OF SUBGRADE SOILS

Table 3-2. Choice of CBR Tests for Pavement Design

Goal: To design the pavement on the basis of the predominant subgrade moisture content anticipated in the life of the pavement.

Basic Test: In the absence of reliable field information this moisture content is considered to be represented by 4 days soaking of the compacted subgrade soil in the CBR molds.

Exceptions: (1) Where rainfall is light and the ground water table is low, substantial reductions can be made in the pavement thickness developed from soaked CBR tests (see section 7).

(2) The in-place CBR test may be used for subgrade soils where little increase in moisture is anticipated, such as:

(a) Coarse grained cohesionless soils.

(b) Soils which are at least 80 percent saturated in the natural site.

(c) Soils under existing adjacent pavements which can be used as indicators for the planned construction. Subgrade soils under pavements at least 3 years old are considered to have reached equilibrium moisture conditions. (Caution: Use care in making assumptions regarding similarity of soil types, drainage, and topography).

(3) Where subgrade compaction is not feasible or desirable as with saturated fine sands or silts, hard clays, and expansive soils, special approaches are necessary (see table 3-5).

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Table 3-3. Subgrade Compaction Requirements
Depth Below Pavement Surface to Top of Subgrade (feet)

	Army Class I Pavement		Army Class II Pavement		Army Class III Pavement	
	15 Kip <u>Gross Wt</u>	Less Than <u>15 Kips</u>	30 Kip <u>Gross Wt</u>	Less Than <u>30 Kips</u>	100 Kip <u>Gross Wt</u>	Less Than <u>100 Kips</u>
Cohesionless Subgrade						
100%						
B	1.0	1.0	1.5	1.0	2.0	1.5
C	1.0	0.5	1.0	0.5	1.5	1.5
95%						
B	1.5	1.5	2.0	1.5	4.0	2.5
C	1.5	1.0	1.5	1.5	3.0	2.5
90%						
B	2.5	2.0	3.0	2.0	6.5	4.0
C	2.0	1.5	2.5	1.5	4.5	3.5
85%						
B	3.0	2.5	4.0	3.0	7.5	5.5
C	2.5	2.0	3.5	2.5	6.5	5.0
Cohesive Subgrade						
100%						
B	0.5	0.5	1.0	0.5	1.0	0.5
C	0.5	0.5	0.5	0.5	0.5	0.5
95%						
B	1.0	1.0	1.0	1.0	2.0	1.5
C	1.0	0.5	1.0	0.5	2.0	1.5
90%						
B	1.5	1.0	1.5	1.5	3.0	2.0
C	1.5	1.0	1.5	1.0	2.5	2.0
85%						
B	1.5	1.5	2.0	1.5	4.0	3.0
C	1.5	1.0	1.5	1.5	3.5	2.5

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- Replace with suitable borrow material.
- Raise the grade so that natural densities meet required values.
- Stabilize: See EM 1110-3-137.

Thickness of compacted lifts can vary with type of equipment used, classification of soil, number of passes, and compaction requirements. Guidelines for varying thicknesses of lifts for 95 to 100 percent compaction are shown in table 3-4.

a. Additional requirements. In addition to the above requirements:

- (1) Compact subgrade to a minimum of 95 percent for a depth of 6 inches below subbase.
- (2) Place fill in subgrades at a minimum of 95 percent compaction for cohesionless soils and 90 percent for cohesive soils.

b. Special cases. Although compaction increases the strength of most soils, some soils lose strength when scarified and recompacted and some soils shrink or expand excessively under moisture changes. When these soils are encountered, special treatment is required. (See table 3-5 for recommended procedures.)

3-5. Subgrade stabilization. Subgrade material may be stabilized (a) to improve the soil quality by reducing plasticity and controlling expansion, (b) to provide a "working platform," and (c) to upgrade the material for use as subbase. Soil stabilization for quality improvement is discussed in EM 1110-3-137.

3-6. Fill quality. In general, coarse grain material is preferred to fine grain material. Fill material should be restricted as follows:

- Do not use expansive soils.
- Do not use peat or organic clays and silts.

Table 3-4. Compaction Equipment and Methods

Equipment type	Applicability	Requirements for Compaction of 95 to 100 Percent Modified AASHO Maximum Density			Dimensions and weight of equipment	Possible variations in equipment
		Compacted lift thickness, in.	Passes or coverages	Soil type		
Sheepfoot rollers	For fine-grained soils or dirty coarse-grained soils with more than 20 percent passing the No. 200 sieve. Not suitable for clean coarse-grained soils.	6	4 to 6 passes for fine-grained soil; 6 to 8 passes for coarse-grained soil	Fine-grained soil PI > 30 Fine-grained soil PI < 30 Coarse-grained soil	Foot contact area, in. ² 5 to 12 7 to 14 200 to 400	For airfield work, drum of 60-in dia., loaded to 1.5 to 3 tons per linear foot of drum generally is utilized. For smaller projects 40-in dia. drum, loaded to 0.75 to 1.75 tons per linear foot of drum is used. Foot contact pressure should be regulated so as to avoid shearing soil on the third or fourth pass.
Rubber tire rollers	For clean, coarse-grained soils with 4 to 8 percent passing the No. 200 sieve. For fine-grained soils or well-graded, dirty coarse-grained soils with more than 8 percent passing the No. 200 sieve.	10	3 to 5 coverages	Tire inflation pressures of 60 to 80 psi for clean granular material or base course and subgrade compaction. Wheel load 18,000 to 25,000 lb.	Tire inflation pressures of 60 to 80 psi for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large size tire with pressure of 40 to 50 psi.	Wide variety of rubber tire compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel load if lift thickness is decreased. For cohesionless soils, large-size tires are desirable to avoid shear and rutting.
Smooth wheel rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures.	8 to 12	4 coverages	Tandem type rollers for base course or subgrade compaction, 10 to 15 ton weight, 300 to 500 lb per linear inch of width of rear roller.	3-wheel rollers obtainable in wide range of sizes. 2-wheel tandem rollers are available in the range of 1 to 20 ton weight. 3-axle tandem rollers are generally used in the range of 10 to 20 ton weight. Very heavy rollers are used for proof rolling of subgrade or base courses.	
Vibrating baseplate compactors	May be used for fine-grained soils other than in earth dams. Not suitable for clean well-grained sands or silty uniform sands.	6 to 8	6 coverages	3-wheel roller for compaction of fine-grained soil; weights from 5 to 6 tons for materials of low plasticity to 10 tons for materials of high plasticity.	Single pads or plates should weigh no less than 200 lb. May be used in tandem where working space is available. For clean coarse-grained soil, vibration frequency should be no less than 1,600 cycles per minute.	
Crawler tractor	Best suited for coarse-grained soils with less than 4 to 8 percent passing No. 200 sieve. Best suited for materials with 4 to 8 percent passing No. 200, placed thoroughly wet.	8 to 10	3 coverages	4 to 6 in. for silt or clay, 6 in. for coarse-grained soils.	No smaller than D8 tractor with blade, 34,500 lb weight, for high compaction.	Tractor weights up to 60,000 lb.
Power tamper or rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	10 to 12	3 to 4 coverages	4 to 6 in. for silt or clay, 6 in. for coarse-grained soils.	30-lb minimum weight. Considerable range is tolerable, depending on materials and conditions.	Weights up to 250 lb, foot diameter 4 to 10 in.

Table 3-5. Special Cases of Subgrade Treatment

<u>Soil Type</u>	<u>Characteristics and Identification</u>	<u>Recommended Subgrade Procedures</u>
Stiff, preconsolidated clays	These soils normally classified as CH or occasionally CL, may have greater strength in the undisturbed condition than when reworked and compacted to maximum density. Investigate comparative CBR's in both these conditions. Check expansive tendencies.	If undisturbed condition is stronger, do not attempt to compact. Minimize disturbance as much as possible. Use in-place CBR or soaked undisturbed samples for design. Check table 3-3 to assure compaction requirements are met.
Silts and very fine sands	These soils, normally classified as ML, become quick or spongy when compacted in presence of high water table or when saturated. Occasionally water may move up into subbase or base course during compaction.	Lower water table and dry out if feasible. Otherwise, do not attempt to compact. Remove and replace or blanket with sand or well graded granular material. Do not place open base or subbase directly on these soils.
Expansive soils	All clay soils have the potential for expansion under moisture changes. If test in CBR mold shows swell greater than 3 percent, special attention is necessary. Certain clays, especially in arid areas, are highly expansive and require deep subgrade treatment. These clays generally slake readily and have liquid limits above 40, plasticity index above 25, natural moisture close to the plastic limit, and activity ratio of 1.0 or greater.	For nominally expansive soils, determine optimum water content, compaction effort and overburden to control swell. Use corresponding CBR and density values for design. Particular attention should be directed to areas where soil profile is nonuniform. Field control of compaction moisture is critical. For highly expansive soils consider (a) replacement to depth of moisture equilibrium, (b) raising grade, (c) lime stabilization, (d) prewetting or other.

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